

Elk Hoof Disease in Southwest Washington

Kristin Mansfield DVM MPVM

**Fish and Wildlife Commission
Meeting
August 8, 2014**

Photo by S. McCorquodale

Wild Ungulate Hoof Diseases

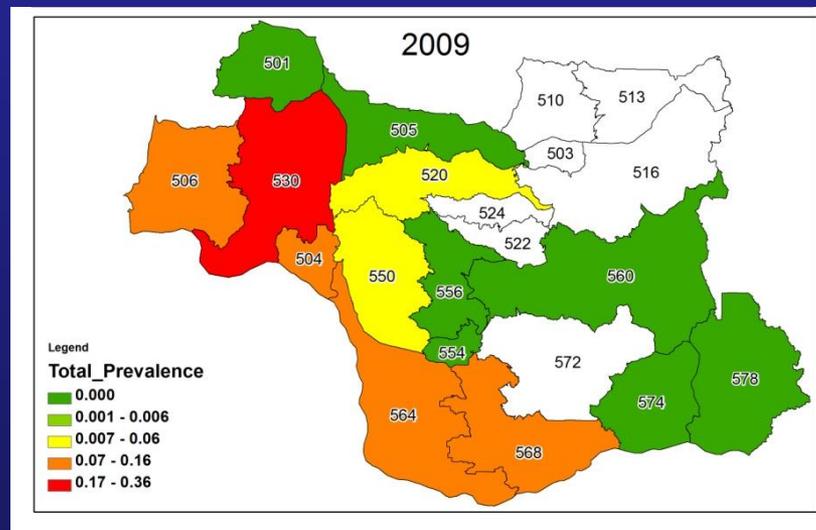
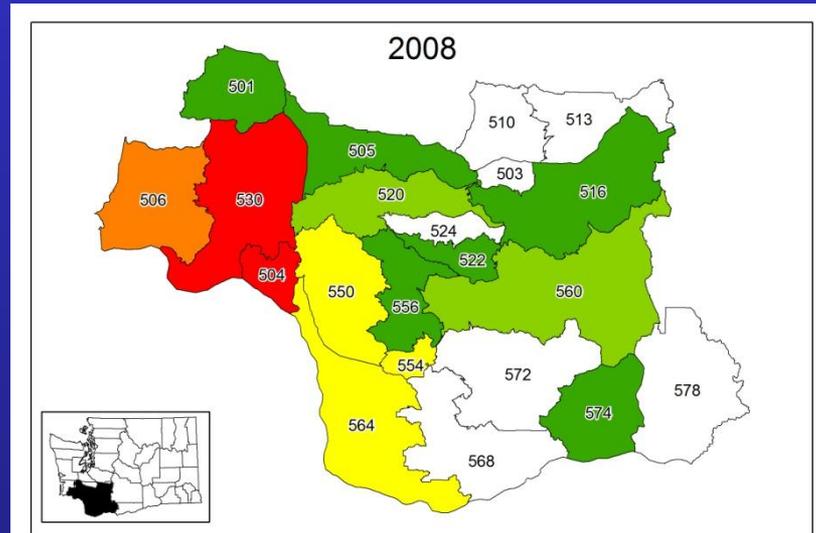
- Usually sporadic and many different causes
- Below are photos from an elk, a moose, and a mule deer, each with a different hoof disease, all collected during Fall 2012 in Eastern WA



Examples of Deformed Hooves



Prevalence and Distribution 2008-2009



Novel Hoof Disease in Elk?



Spillover from Domestic Animals?



Common Hoof Diseases of Livestock

Foot Rot of Domestic Sheep



Digital Dermatitis of Cattle



Diagnostic Investigation Partners

Assistance of Veterinary Personnel From:

- WDFW
- Washington State University
- University of Washington
- ODFW
- Oregon State University
- University of Wisconsin
- Tufts University
- WSDA

Samples Sent to Veterinary Diagnostic or Research Labs At:

- Washington State University
- University of Idaho
- Colorado State University
- University of Wyoming
- University of Liverpool (U.K.)
- USDA National Veterinary Services Laboratory
- USDA National Animal Disease Center
- UC Davis

Collections

- **March 2009 :**
 - 3 control
 - 5 affected area
 - **Feb/Mar 2013:**
 - 3 control
 - 4 control
 - 9 affected area
 - **August 2013:**
 - 2 control
 - 5 affected area
 - **January 2014:**
 - 2 control
 - 9 affected area
- adult cows**
 - East of I-5
 - Lewis/Cowlitz Co.
 - 9-10 month old calves**
 - Pacific County
 - Yakima / Kittitas Co.
 - Lewis / Cowlitz Co.
 - 3 month old calves**
 - Grays Harbor Co.
 - Lewis Co.
 - 8 month old calves**
 - Kittitas Co.
 - Cowlitz, Wahkiakum, Pacific, Grays Harbor Co.



Nostrils			
Oral Cavity			
Tongue		H	lung worms (mund/whee) coming out in + taken for protozoal
Skin (earnotch, vent neck)		H	
Vulva/Penis			
Anus			
Mammary gland			
INTERNAL EXAM			
Brain		H, VI, T - foil	also took meninges
Subcutaneous tissue			
Pre-scap LN (scap LN)		H (cassette)	
Trachea (w/esoph & thy)		H	
Thyroid & parathyroid		H	
Blood - RTT & LTT		S	pericardial fluid
Bronchi/bronchioles			lung worm
Lung		VI	
DV x 2 sides		H	
CV x 2 sides		H	
Mediastinal LNs (med LN)		H (cassette)	
Thymus		VI	not observed
Heart (long sec of walls)		H	
Major vessels			
Diaphragm		H	
Mesenteric fat		T- foil	very little mesenteric fat
Liver		H, VI, T x 3 - foil	
Spleen		H, VI	
Mesenteric LNs (mes LN)		H (cassette)	
Kidney		H (L&R), VI, Tx3 - foil	
Adrenal glands (L & R)		H	
Ovaries/Testicles			
Uterus			immature
Bladder		H	
Urine		S (RT vial)	empty bladder
Skeletal muscle		H, S (EtOH, cryo)	
Popliteal LN (pop LN)		H (cassette)	
Bone Physis		H	
Bone marrow (mid-femur)		S - bag	gelatinous
Esophagus			
Rumen		H	Look for ulcers!
Rumen contents		S - bag	
Reticulum			
Omasum			

Diagnostic Investigation

- Gross necropsy
- Radiology
- Histology
- Parasitology
- Virus isolation
- Trace minerals
- Routine bacteriology
- Specialized bacteriology



Diagnostic Testing & Results

Radiology at CSU

- ✓ No significant primary lesions

Histology at WSU

- ✓ NSF above hooves, even in severely affected individuals

Parasitology at WSU

- ✓ Similar parasite loads in all groups

Diagnostic Testing & Results

Virus Isolation at UWyo

- ✓ An adenovirus isolated from one eastside control, otherwise negative

Trace Minerals at UI

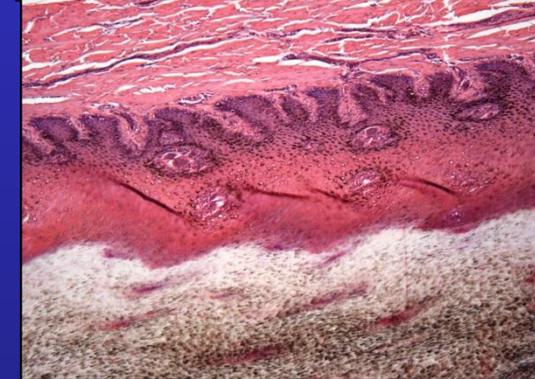
- ✓ Low selenium and copper, as expected

Serology at WSU and NVSL

- ✓ No significant titers to BVD, EHD, BT, MCF, VSV

Diagnostic Conclusions

- Copper and selenium deficient
 - possible impacts on general health and immunity
- Primary hoof disease with no other significant tissue involvement



SEVERE HOOF DISEASE IN FREE-RANGING ROOSEVELT ELK (*CERVUS ELAPHUS ROOSEVELTI*) IN SOUTHWESTERN WASHINGTON, USA

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⁴ Corresponding author (email: Sushan.Han@Colostate.edu)

ABSTRACT: Reports of free-ranging Roosevelt elk (*Cervus elaphus roosevelti*) with abnormal hooves and lameness increased significantly in southwestern Washington, USA, during winter 2008. In March 2009 we examined five severely affected elk with clinical lameness from this region to characterize hoof lesions, examine the general health of affected elk, and potentially identify etiologies causing hoof disease. Three clinically normal elk from an adjacent but unaffected region were also collected as normal controls. Grossly, affected elk had deformed hooves that were asymmetrical, markedly elongated, and curved or broken, as well as hooves with sloughed horn. Most affected elk had severe sole ulcers with extensive laminar necrosis and pedal osteomyelitis. Histopathology of normal and abnormal hooves identified acute and chronic laminitis in all affected elk and one control elk. Hepatic copper and selenium levels in all affected and control elk were also deficient, and hoof keratin copper levels were low. No significant underlying systemic or musculoskeletal disease was detected in the affected elk, and attempts to isolate bacterial and viral pathogens were unsuccessful. A primary cause of hoof deformity was not definitively identified in this chronically affected group. Studies to identify infectious hoof disease and to characterize acute and subacute lesions are underway.

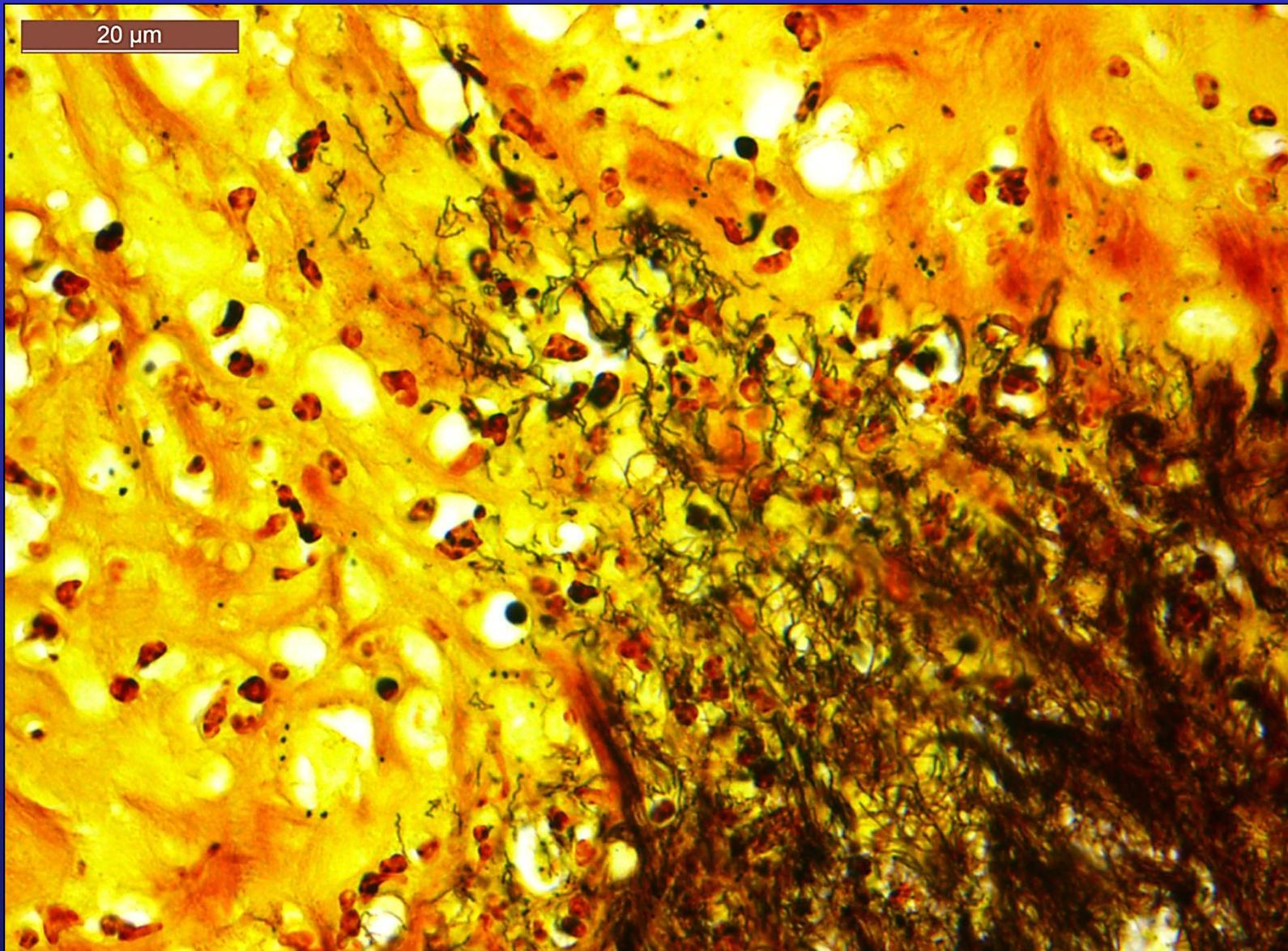
Key words: *Cervus elaphus roosevelti*, copper deficiency, elk, hoof disease, lameness, laminitis, selenium deficiency, sole ulcer.

Winter 2013 Effort





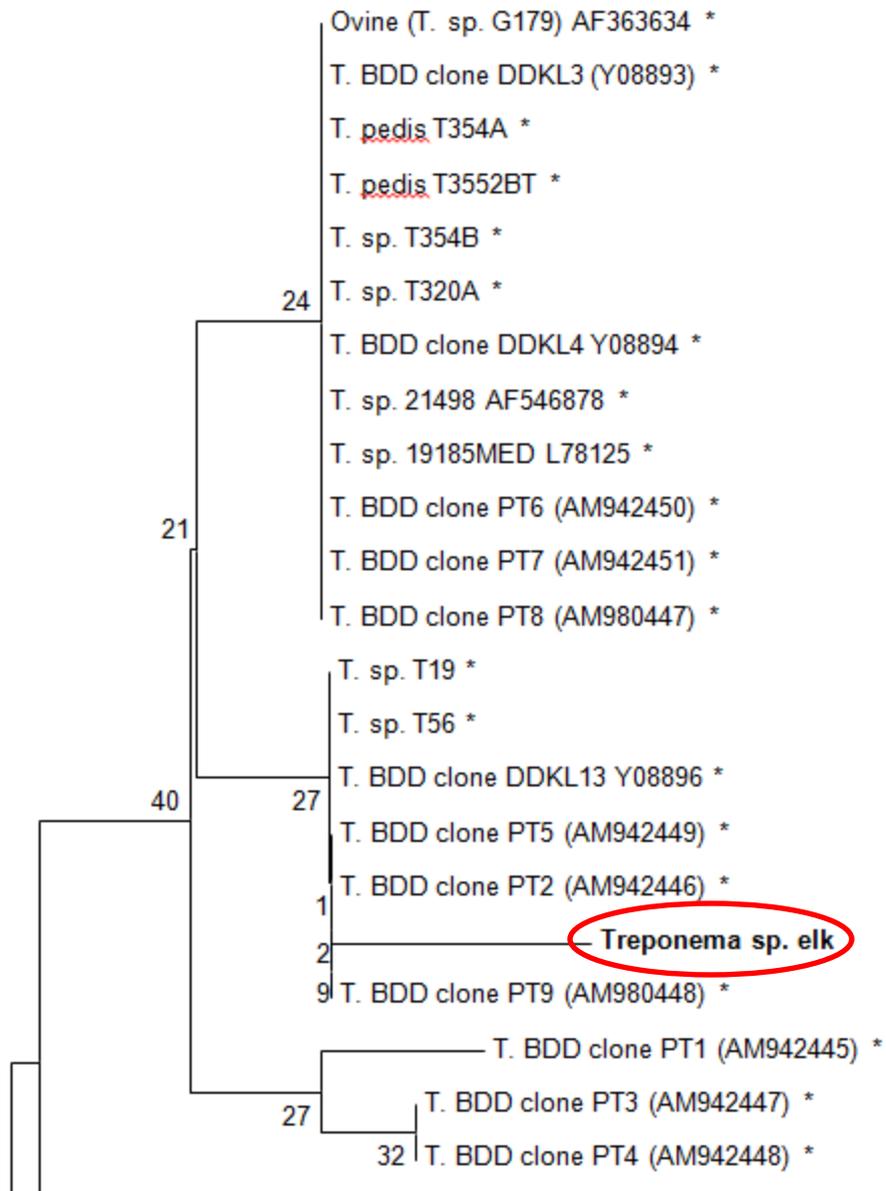
2013 – 9 month elk



Disease Status and Spirochete Detection

Winter 2013

ELK ID	County	Population Status	Spirochetes in Culture	<i>Treponema</i> sp. PCR	Spirochetes on Histology
001	Pacific	unaffected	ND	neg	neg
002	Pacific	unaffected	ND	neg	neg
003	Pacific	unaffected	ND	neg	neg
004	Kittitas	unaffected	ND	neg	neg
005	Kittitas	unaffected	ND	neg	neg
006	Yakima	unaffected	ND	neg	neg
007	Yakima	unaffected	ND	neg	neg
008	Lewis	affected	pos	pos	pos
009	Lewis	affected	neg	neg	neg
010	Lewis	affected	neg	pos	neg
011	Lewis	affected	neg	neg	pos
012	Lewis	affected	pos	pos	pos
013	Cowlitz	affected	neg	pos	pos
014	Cowlitz	affected	neg	neg	neg
015	Cowlitz	affected	pos	neg	neg
016	Cowlitz	affected	pos	neg	neg





Winter 2013 Diagnostic Results Summary

Findings very similar to 2009

- Chronic hoof changes even in 9 month old calves
- Pathogenic treponemes in diseased hooves
- Confirmed that disease limited to hooves
- Other tissues, including meat, are not affected



Summer 2013 Effort



August 2013



Disease Status and Spirochete Detection

August 2013

ELK ID EL13-	County	Population Status	Sample	Spirochetes in Culture	Spirochetes on Histology	Sequencing UoL
017	Grays Harbor	unaffected	CB or IDS	neg	neg	
018	Grays Harbor	unaffected	CB or IDS	neg	neg	
021	Lewis	affected	IDS	neg	neg	
022	Lewis	affected	gross lesion	pos	neg	
022	Lewis	affected	IDS	neg	neg	<i>T. medium</i> (2 isolates)
022	Lewis	affected	contra	neg	neg	
023	Lewis	affected	gross lesion	pos	neg	
023	Lewis	affected	CB	neg	neg	<i>T. phagedenis</i> subsp. <i>vaccae</i> (2 isolates)
023	Lewis	affected	contra	neg	neg	
024	Lewis	affected	gross lesion	pos	neg	
024	Lewis	affected	CB	neg	neg	<i>T. medium</i> <i>T. phagedenis</i> subsp. <i>vaccae</i>
024	Lewis	affected	contra	neg	neg	
025	Lewis	affected	CB	neg	neg	<i>T. medium</i>
025	Lewis	affected	IDS	neg	neg	

Summary Through October 2013

- **Adult animals**
 - **Severe chronic hoof lesions; unable to determine primary lesion(s)**
- **9-10 month old calves**
 - **Severe chronic lesions; unable to determine primary lesion(s)**
 - **Treponemes detected in diseased hooves**
- **3 month old calves**
 - **Suggestion of early lesions grossly; unable to confirm histologically**
 - **Treponemes isolated from suspected gross lesions**

January 2014 Effort



8 month old elk calf



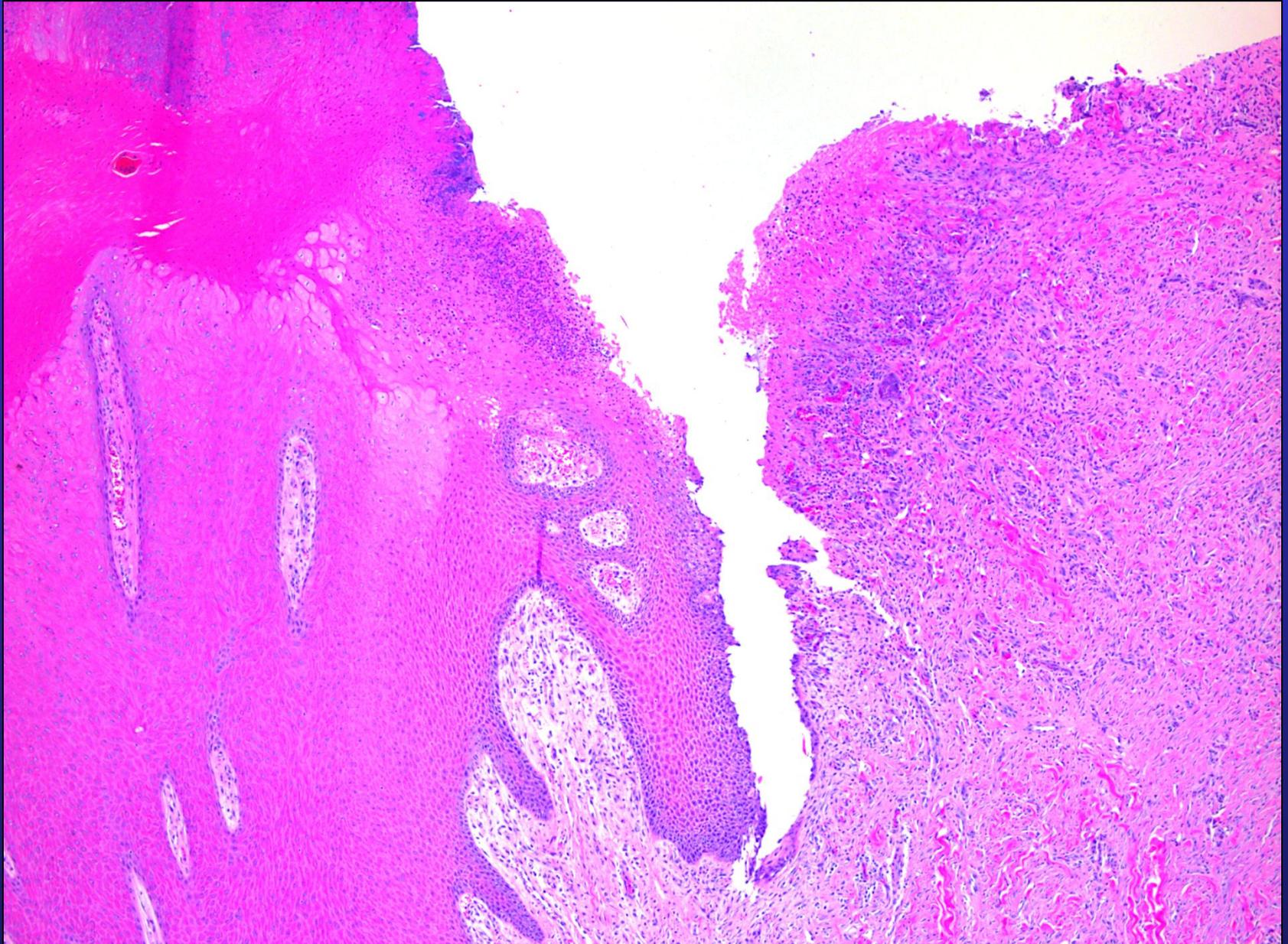


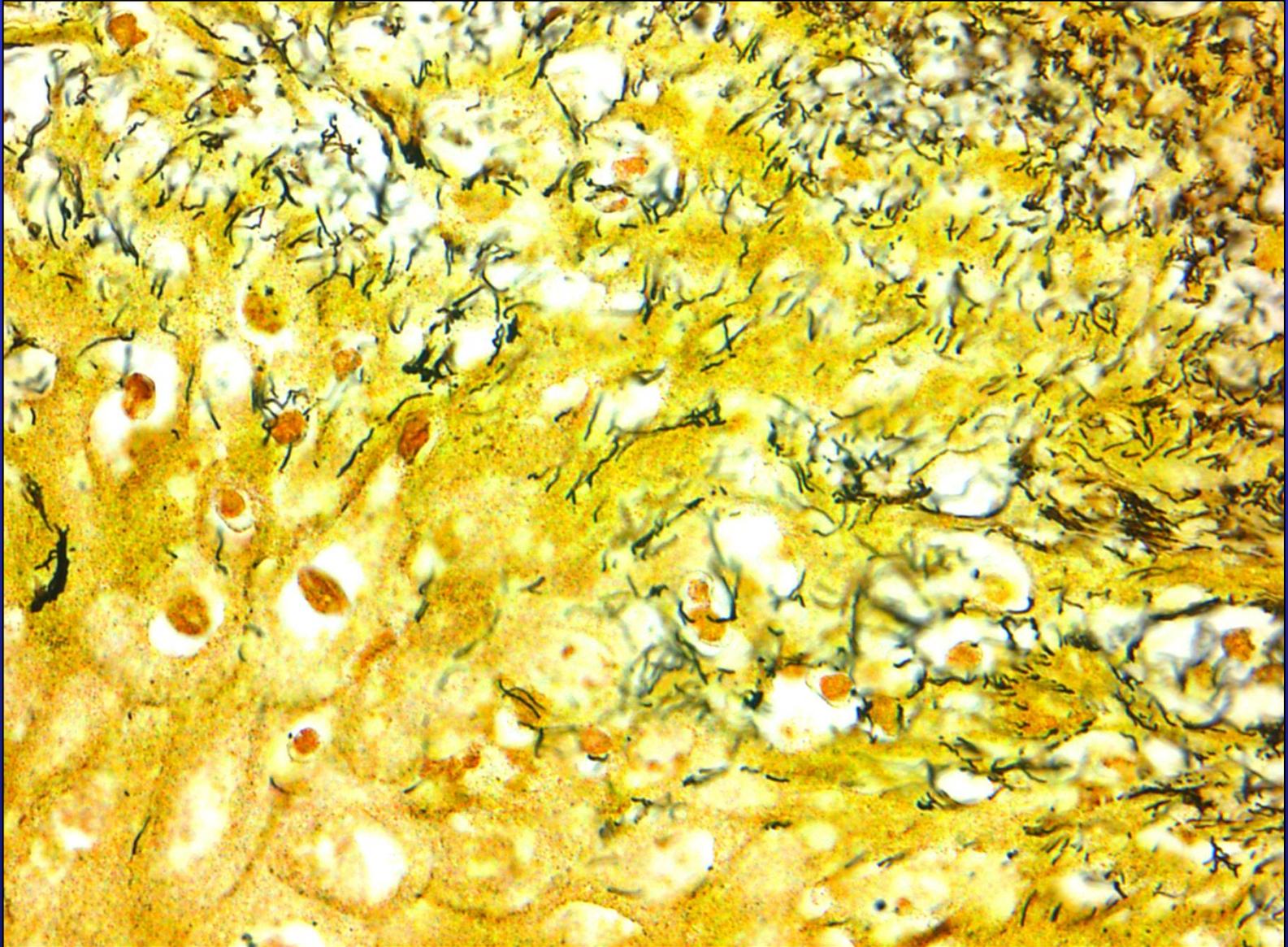
8 month old elk calf



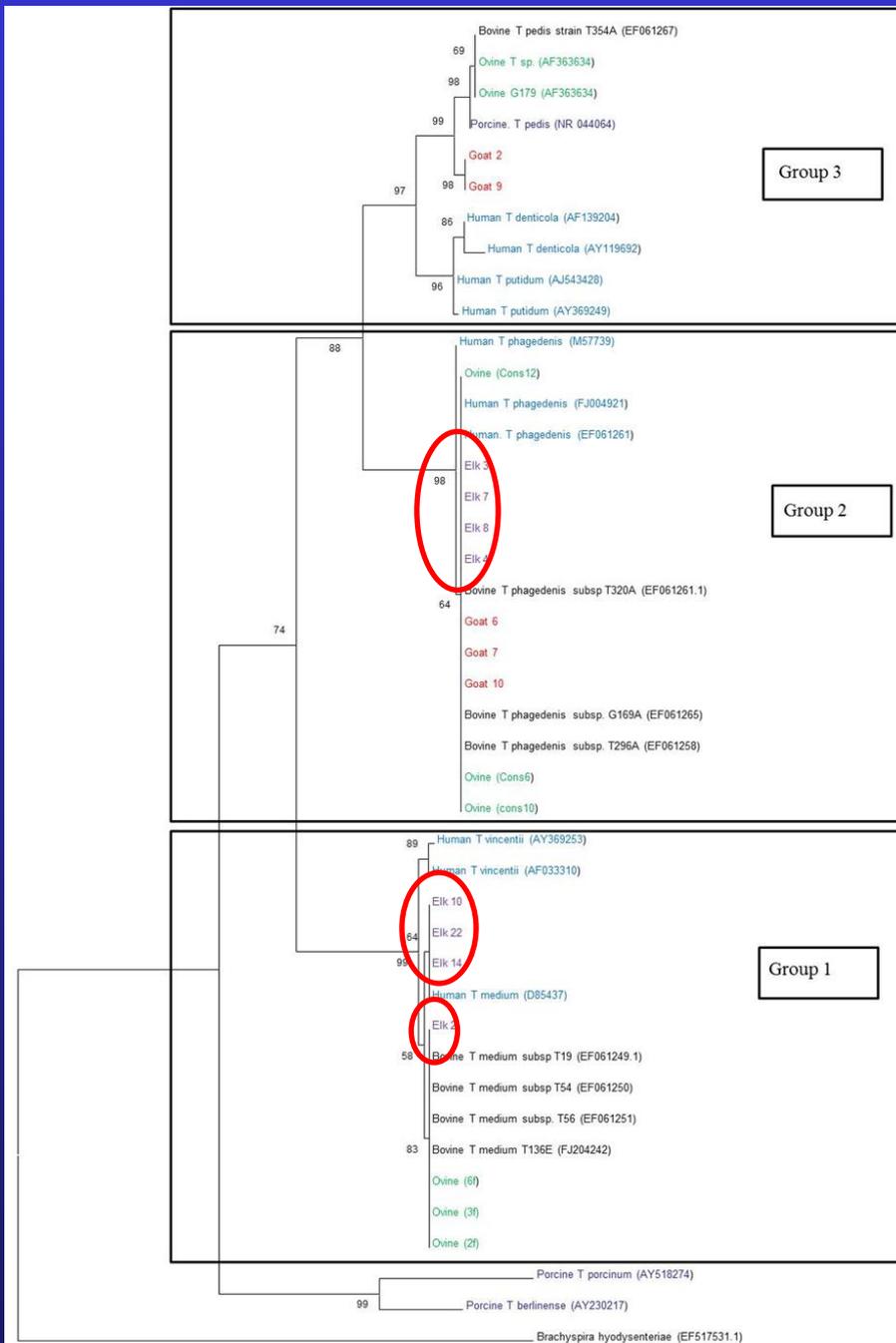




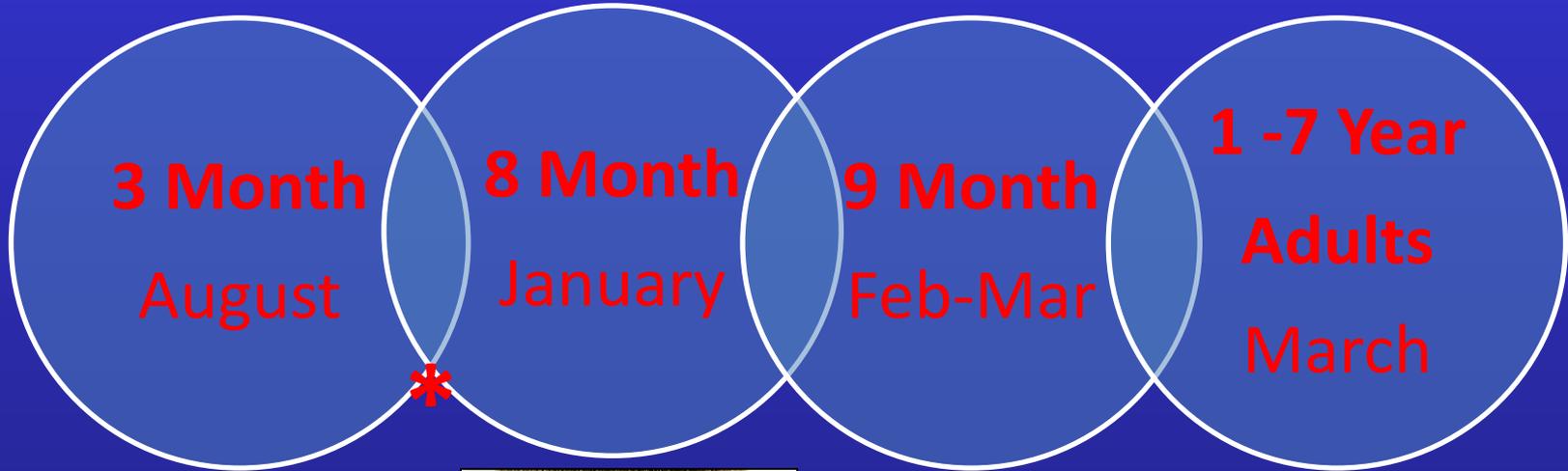




Clegg et al.
(submitted to J. Clin. Micro
2014)



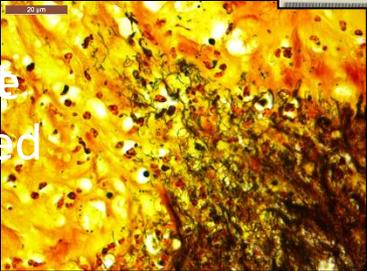
Summary



- Sporadic bacterial infections
- Secondary infections
- Pododermatitis / overgrowth
- Mild debilitation / emaciation



- Wet over nutrition
- Animal environment
- Moisture exposed
- Minerals low



- Wet environment
- As a result concentrate
- Dry environment

What Do We Know About Digital Dermatitis?

- Emerged as a significant disease of dairy cattle in the US in the mid-1990s; other countries shortly thereafter

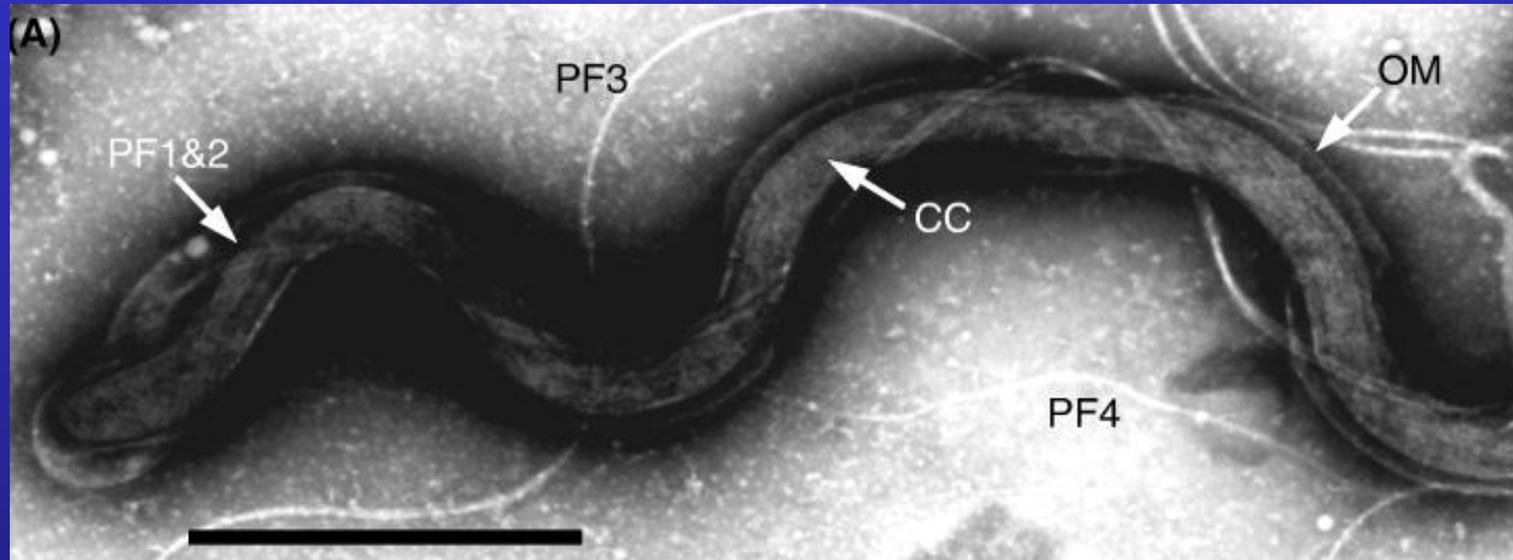


What Do We Know About Digital Dermatitis?

- 2007 NAHMS Survey
 - Present in 70% of dairies nationwide
 - Responsible for 50% of lameness cases within



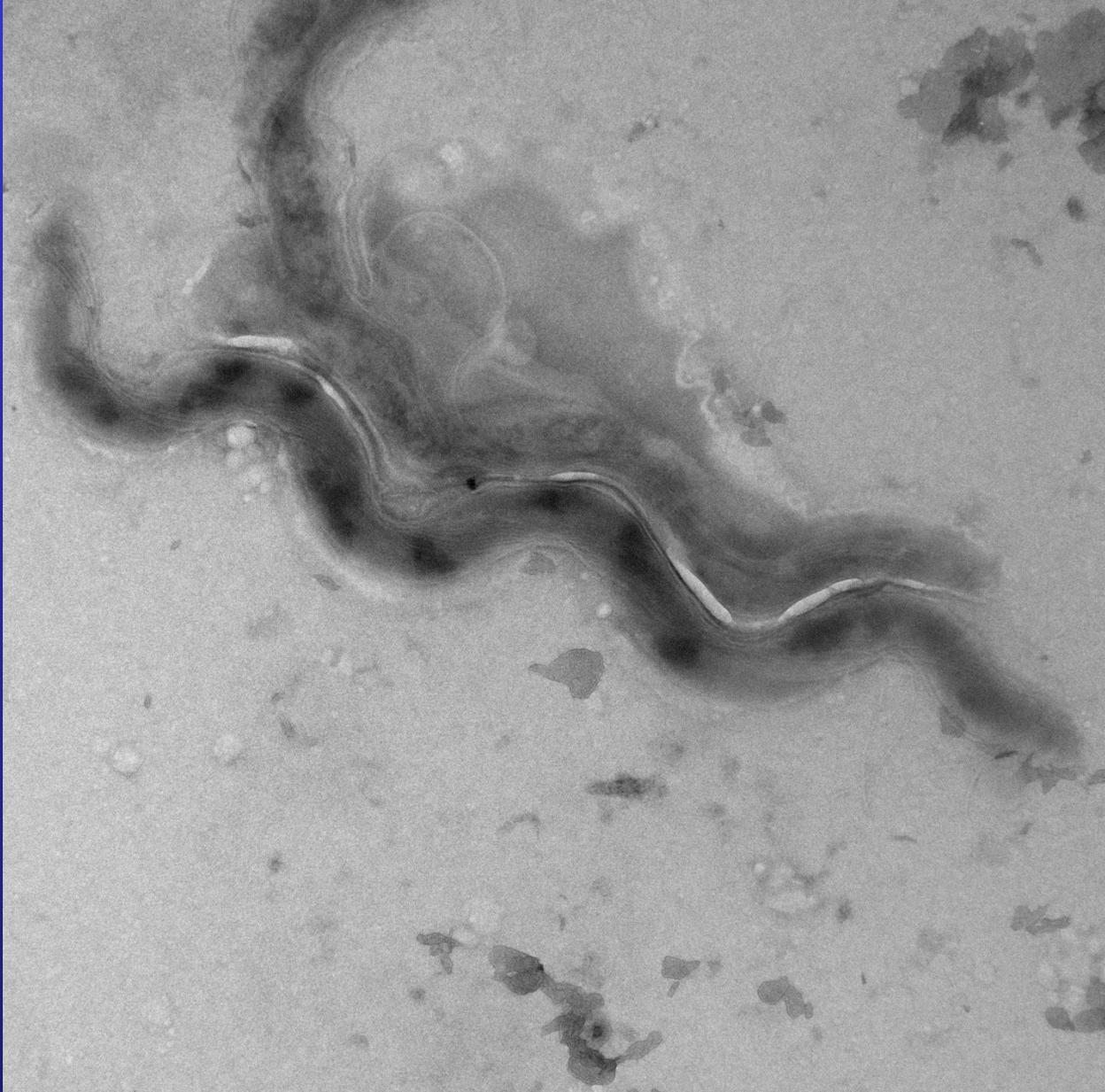
From tooth to hoof: treponemes in tissue-destructive diseases



Treponemes: Spiral shaped bacteria, double membrane, flagella sandwiched between them.

Many innate immunity triggers hidden, thin corkscrew shape facilitates deep tissue penetration.

Most anaerobic (do not use oxygen), slow growth rate, very fastidious, amino acid users, produce volatile fatty acids



Jen_Wilson-Welder_058

E45 B

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Camera: Hamamatsu ORCA HR Camera , Exposure(ms): 1300 Gain: 2, Bin: 1

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600 nm

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National Animal Disease Center

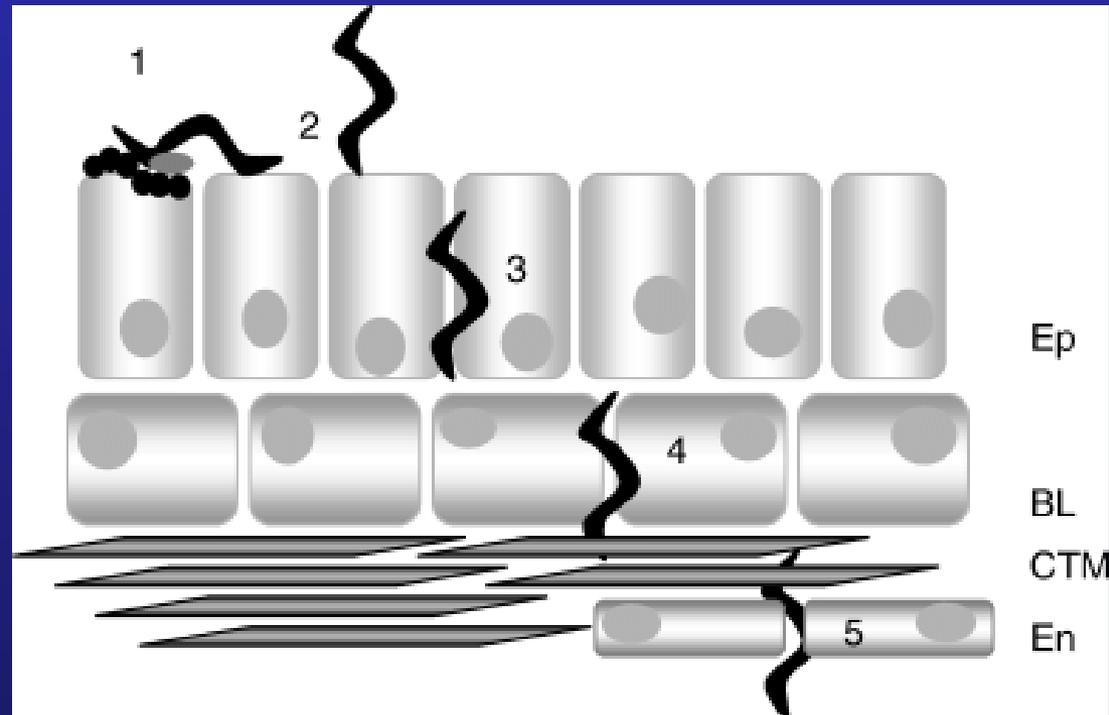
From tooth to hoof: treponemes in tissue-destructive diseases

Similarity to human periodontal disease

Colonization in conjunction with other bacteria: Fusobacterium, Porphyromonas and Streptococcus

Alterations in microenvironment allowing colonization with Treponemes

Treponemes have "virulence factors" that allow for deep penetration of epithelial and basal dermal layers



Journal of Applied Microbiology

Volume 94, Issue 5, pages 767-780, 10 APR 2003 DOI: 10.1046/j.1365-2672.2003.01901.x

<http://onlinelibrary.wiley.com/doi/10.1046/j.1365-2672.2003.01901.x/full#f3>

Bovine Digital Dermatitis

- Leading cause of lameness in dairy cattle
 - Increasing incidences in beef cattle
- Severe economic losses due to decreased production, premature culling, footbaths/treatment
 - A lame cow cost the producer \$346 per incident
 - 2007 Calif. Dairy Industry estimates \$1.5-5 million lost
 - 20% of culled cattle
- Animal welfare issue



Persistence of DD organisms in environment

Vet Microbiol. 2012 Apr 23;156(1-2):102-9. doi: 10.1016/j.vetmic.2011.09.029. Epub 2011 Oct 2.

Host and environmental reservoirs of infection for bovine digital dermatitis treponemes.

Evans NJ¹, Timofte D, Isherwood DR, Brown JM, Williams JM, Sherlock K, Lehane MJ, Murray RD, Birtles RJ, Hart CA, Carter SD.

-Treponemes found in oral cavity and rectal tissue of cattle from farms with DD

Appl Environ Microbiol. 2014 May 9. [Epub ahead of print]

Discovery of bovine digital dermatitis-associated Treponema in the dairy herd environment using a targeted deep-sequencing approach.

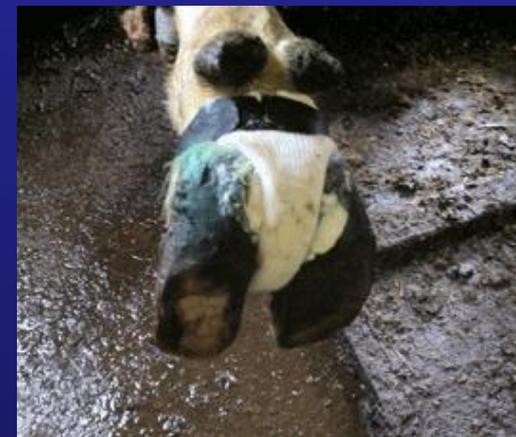
Klitgaard K¹, Nielsen MW, Ingerslev HC, Boye M, Jensen TK.

-Found DD Treponemes in manure slurry

Our Lab: viable when stored refrigerated for prolonged periods

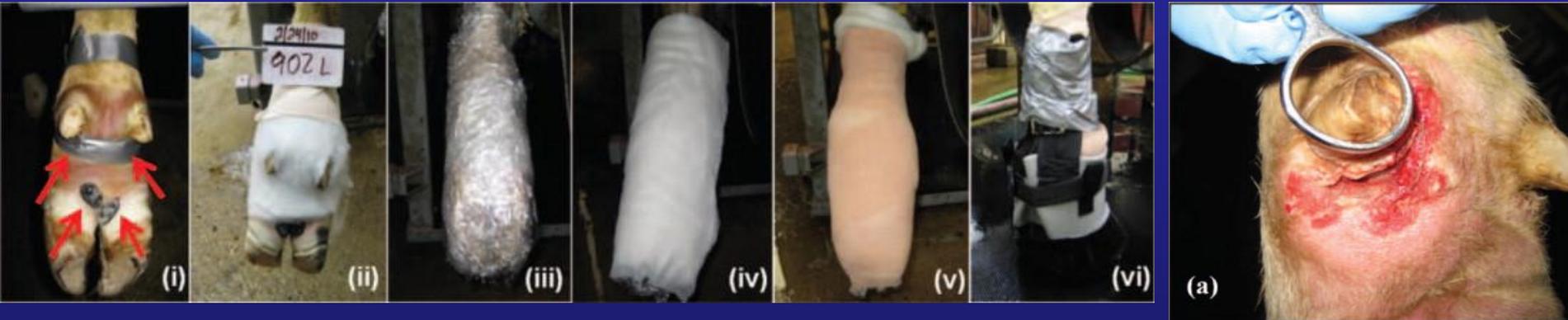
DD Treatment and Control Options:

- NO VACCINE
 - Early attempts with Bacteroides and Treponema non-efficacious
- Footbaths: copper sulfate, zinc sulfate, formalin, antibiotics
 - daily use, 2-3x week
 - Not in winter in upper-midwest
 - Environmental and human toxicity issue
- Trimming and wrapping: topical antibiotics, copper sulfate
- Topical application of lincomycin (antibiotic) wraps alone required retreatment and were more likely to become active.
 - Berry et al., The Veterinary Journal, 193 (2012) 654-658



Trouble with DD:

- 20 years of study, no solid answers!!
- No infection model
 - Some success with macerated lesion material
 - 60% rate, LONG incubation, looks different



A. Gomez, N.B. Cook, N.D. Bernardoni, J. Rieman, A.F. Dusick, R. Hartshorn, M.T. Socha, D.H. Read, D. Döpfer, An experimental infection model to induce digital dermatitis infection in cattle, *Journal of Dairy Science*, Volume 95, Issue 4, April 2012, Pages 1821-1830, ISSN 0022-0302, 10.3168/jds.2011-4754.
(<http://www.sciencedirect.com/science/article/pii/S0022030212001476>)

DD lesions

- Papillomatous digital dermatitis, Hairy heel warts, strawberry warts, Mortellaro disease
- Circular to oval distinct region
- Foul smell
- Hairless, mature lesions can have keratin-like protrusions
- Moist, prone to bleeding when probed
- Extremely painful granular tissue



What Do We Know About Digital Dermatitis?

- Emerged as a significant disease of dairy cattle in the US in the mid-1990s; other countries shortly thereafter
- 2007 NAHMS Survey
 - Present in 70% of dairies nationwide
 - Responsible for 50% of lameness cases within dairies
- Sheep form (contagious ovine digital dermatitis-CODD) emerged in the UK shortly after cattle form

BACTERIAL PATHOGENICITY

Identification of Spirochetes Associated with Contagious Ovine Digital Dermatitis[†]

G. Sayers¹, P. X. Marques¹, N. J. Evans³, L. O'Grady¹, M. L. Doherty¹,
S. D. Carter³ and J. E. Nally^{1,2,*}

+ Author Affiliations

ABSTRACT

Spirochetes of the genus *Treponema* were cultured from 7 of 10 cases of dermatitis in :

Treponema remaining cul medium/*Trepanedenticola/Tre*

Bovine digital dermatitis and severe virulent ovine foot rot: a common spirochaetal pathogenesis.

Dhawi A¹, Hart CA, Demirkan I, Davies IH, Carter SD.

+ Author information

Abstract

A potential pathological role for spirochaetes in bovine digital dermatitis (bovine DD) and severe virulent ovine foot rot (SVOFR) has been considered and a treponeme isolate obtained from each disease in the UK. In this work, we have investigated the hypothesis that the two diseases may have a shared (common) spirochaetal aetiology. Experiments were designed to identify serological similarities and differences between the two spirochaetes; an enzyme-linked immunosorbent assay (ELISA) was developed to detect anti-treponeme antibodies in the sera of cows and sheep against the two-treponeme isolates. Sera were further tested for antigen reactivity by Western blotting. Cattle and sheep with bovine DD and SVOFR, respectively, had increased seropositivity rates to both treponeme isolates, with different patterns of reactivity between farms. In some cattle herds, significant correlations were shown between antibodies to bovine DD treponemes and SVOFR treponemes ($P < 0.001$). In other herds, there was no apparent cross reaction, suggesting the presence of more than one treponeme in bovine DD on some farms. There was no significant correlation between the two treponeme isolates when ELISA-tested against 58 sheep sera from SVOFR cases ($P > 0.05$); sheep showed strong evidence of reactivity to one or the other treponeme antigens, but never to both. Western blotting against both treponeme antigens showed that they frequently displayed different antigen epitopes, although some minor bands were common to both organisms. The data suggest that there are a number of spirochaetes in UK farms, which could be involved in the pathogenesis of either bovine DD or SVOFR.

Isolation and characterisation of a novel spirochaete from severe virulent ovine foot rot

I. DEMIRKAN, S. D. CARTER, C. WINSTANLEY*, K. D. BRUCE†, N. M. McNAIR‡, M. WOODSIDE§ and C. A. HART*

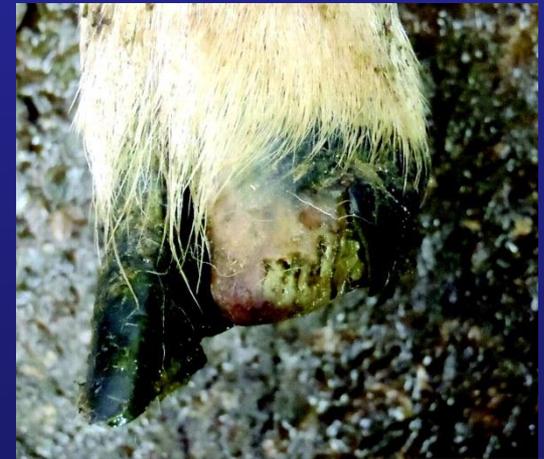
Departments of Veterinary Immunology and *Medical Microbiology and Genitourinary Medicine, University of Liverpool, Liverpool, †Division of Life Sciences, Franklin-Wilkins Building, Kings College, London, ‡Veterinary Research Laboratory, Belfast, Northern Ireland and §Clare Veterinary Group, Ballyclare, Northern Ireland

A novel spirochaete was isolated from a case of severe virulent ovine foot rot (SVOFR) by immunomagnetic separation with beads coated with polyclonal anti-treponemal antisera and prolonged anaerobic broth culture. The as yet unnamed treponeme differs considerably from the only other spirochaete isolated from ovine foot rot as regards morphology, enzymic profile and 16S rDNA sequence. On the basis of 16S rDNA, it was most closely related to another unnamed spirochaete isolated from cases of bovine digital dermatitis in the USA, raising the possibility of cross-species transmission. Further information is required to establish this novel ovine spirochaete as the cause of

Contagious Ovine Digital Dermatitis

Same bacterial community profile as bovine digital dermatitis: multiple **treponeme** species, multiple *Fusobacterium* species, *Peptostreptococcus*, *Streptococcus*, *Staphylococcus*, *Macrococcus* (Firmicutes) and *Dichelobacter*

CODD



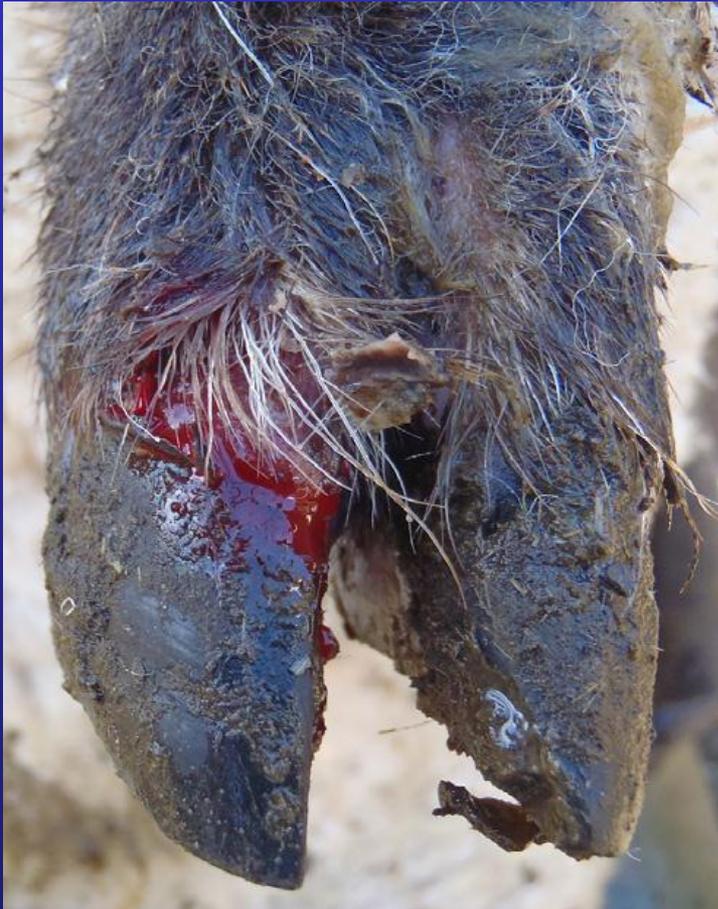
Calvo-Bado L A et al. the ISME Journal (2011) 5, 1426-1437

Duncan J S et al. Veterinary Record 2011;169:606

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Information is subject to changes and amendments over time.

CODD vs. Elk Hoof Disease



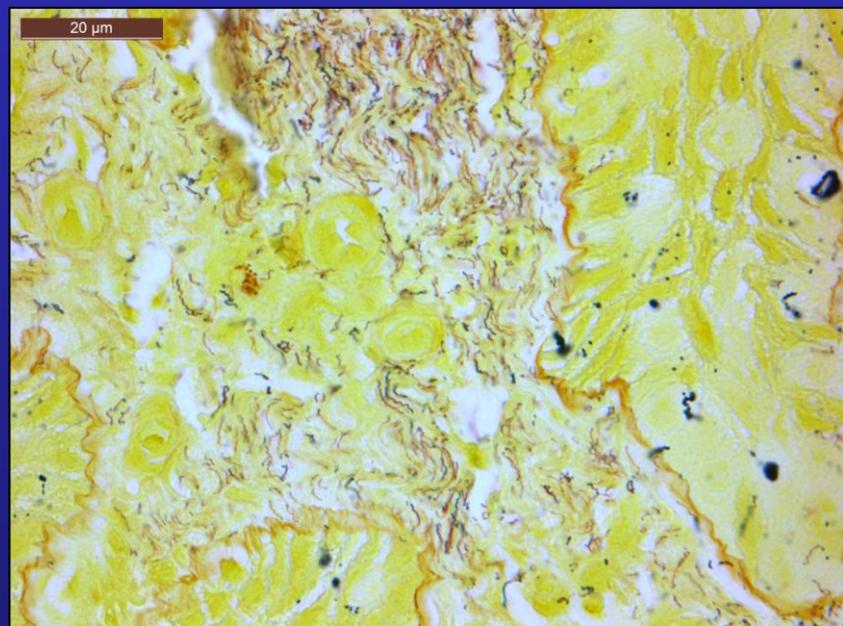
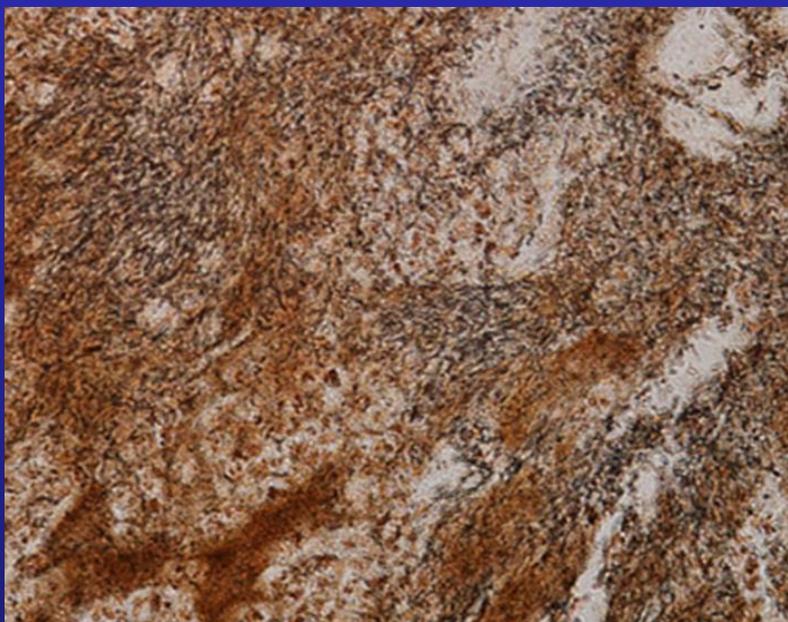
J.S. Duncan, J.W. Angell, S.D. Carter, N.J. Evans, L.E. Sullivan, D.H. Grove-White, Contagious ovine digital dermatitis: An emerging disease, *The Veterinary Journal* (2014), doi: 10.1016/j.tvjl.2014.06.007

CODD vs. Elk Hoof Disease



J.S. Duncan, J.W. Angell, S.D. Carter, N.J. Evans, L.E. Sullivan, D.H. Grove-White, Contagious ovine digital dermatitis: An emerging disease, *The Veterinary Journal* (2014), doi: 10.1016/j.tvjl.2014.06.007

CODD vs. Elk Hoof Disease



CODD of Domestic Sheep



Consensus

TAG June 3, 2014

- Available evidence is most consistent with an infectious bacterial hoof disease
- The disease shares many features and most resembles treponeme-associated contagious ovine digital dermatitis (CODD)
- Environmental factors, including wet conditions, are likely important in disease initiation and propagation

Information Needs

TAG June 3, 2014

- Being maintained in elk population?
- Elk movements/habitat use
- Develop immunity?
- Effects on survival & reproduction
- Progression of disease over time (individual & herd)
- How transmitted?
- Presence in environment (fecal & soil sampling)

FAQs/Concerns

- Live Animal Testing
- Herbicides
- Leptospirosis
- Safety of Meat

Questions?



Photo by Nicholle Stephens